Before the
**FEDERAL COMMUNICATIONS COMMISSION**
Washington, DC 20554

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| In the Matter of | ) | |
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| Amendment of the Commission's Rules with | ) | GN Docket No. 12-354 |
| Regard to Commercial Operations in the 3550- | ) | |
| 3650 MHz Band | ) | |

**COMMENTS OF NOKIA SOLUTIONS AND NETWORKS US LLC**


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July 14, 2014

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**Comments of Nokia Solutions and Networks US LLC**

Nokia Solutions and Networks US LLC ("Nokia Networks") hereby responds to the Commission's *Further Notice of Proposed Rulemaking* ("*3.5GHz Small Cells FNPRM*")[1] seeking comment on specific rules for a new Citizens Broadband Radio Service in the 3550-3650 MHz ("3.5 GHz") band. Nokia Networks continues to believe that the 3.5 GHz band presents an important opportunity to expand mobile broadband connectivity to consumers across the nation and appreciates the Commission's efforts aimed at enhancing the appeal of the band for such purposes.

[1] Commission Seeks Comment on "In the Matter of Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550-3650 MHz Band", GN Docket No. 12-354, Further Notice of Proposed Rulemaking (*FNPRM*), FCC 14-19, Released: April 23, 2014

## Contents



# I. INTRODUCTION

Nokia Networks is the world's specialist in mobile broadband. Innovating at the forefront of each generation of mobile technology, Nokia Networks provides the world's most efficient mobile networks, the intelligence to maximize the performance of these networks, and the services to make it all work seamlessly. Nokia Networks is leading the commercialization of Long Term Evolution (LTE), both its Frequency Division Duplex (FDD) and Time Division Duplex (TDD) versions, in terms of commercial references and live network performance. This includes pioneering efforts in reducing the footprint of mobile base station infrastructure, from compact yet full power macro sites down to the full range of "small cell" solutions. Nokia

Networks also offers the industry's most comprehensive portfolio of services for integrating heterogeneous networks ("HetNets"), encompassing analysis, optimization, deployment and management.

As Nokia Networks and our mobile broadband industry peers consistently reiterate, cleared, exclusively licensed spectrum suitable for mobile networks unquestionably remains the top priority, with low band spectrum particularly ideal for wide area coverage. Nokia Networks also believes, however, that the 3.5 GHz band holds the potential to supplement these networks for capacity improvements in particular.

Nokia Networks applauds the Commission for responding to the significant record already developed in this proceeding. In some important respects, the *3.5GHz Small Cells FNPRM* takes into consideration Nokia Networks' previously offered comments that seek to overcome the unique set of challenges this band presents and provide a greater degree of certainty for investment in small cell deployments. Nokia Networks in particular is pleased that the Commission is adopting a Priority Access tier that corresponds to Nokia Networks' proposed Authorized Shared Access /Licensed Shared Access (ASA/LSA) tier that includes Mobile Network Operators. In the comments that follow, Nokia Networks offers suggestions on crafting a framework that can best enable commercial success while fostering innovative experimentation in the entirety of the 3550-3700 MHz spectrum range.

## II. NOKIA NETWORKS' SIMULATIONS SUGGEST THAT THE EXCLUSION ZONES CAN BE FURTHER REDUCED BY A MORE ACCURATE MODELING OF THE COMMERCIAL SYSTEMS IN THE NTIA SIMULATIONS

Given that the proposed Exclusion Zones in the National Telecommunications and Information Administration's (NTIA) Fast Track Report[2] to protect Federal Navy radar systems would cover approximately 60 percent of the U.S. population[3] when assuming macro-cell deployments of commercial wireless broadband technology and render the investments in this band uncertain, Nokia Networks is of the view that these Exclusion Zones should be further studied in details before they are enforced in the Report and Order. We are therefore encouraged by the fact that in the *3.5 GHz Small Cells FNPRM*, the Commission mentioned that they plan to reassess these Exclusion Zones in light of new technologies envisioned in the *3.5GHz Small Cells FNPRM* and new data from technical studies evaluating the coexistence of radars and wireless broadband services.

The Exclusion Zones in the NTIA report have been realized mostly by calculating link budgets for the interfering paths between radar and WiMAX systems. Any system parameter changes can lead to significantly different exclusion zones. It is anticipated that LTE would become one of the preferred technologies deployed in this band. Therefore, investigating the effect of radars on the 3.5 GHz LTE systems and vice versa is important to understand the impact of mutual interference between systems that will actually have to coexist in this band.

[2] *See* NTIA, An Assessment of the Near-Term Viability of Accommodating Wireless Broadband Systems in the 1675-1710 MHz, 1755-1780 MHz, 3500-3650 MHz, 4200-4220 MHz, and 4380-4400 MHz Bands (rel. October 2010) (NTIA Fast Track Report), available at http://www.ntia.doc.gov/files/ntia/publications/fasttrackevaluation_11152010.pdf.

[3] *See* Fast Track Report at 1-6 – 1-7 and Appendix D and *3.5 GHz NPRM*, 27 FCC Rcd at 15597 and 15601, ¶¶ 6 and 17-18.

A combination of technical and service characteristics for small cell deployments in the 3.5 GHz band has the potential to reduce geographic exclusion zones substantially based on interference from LTE small cells transmissions to radar systems (reducing them from several hundred kilometers to just 10 to 15 kilometers)[4], while still providing necessary protections for incumbents. In that respect, the much lower transmit power typically used in small cells as compared to macro cells will greatly help mitigate interference from the broadband systems into the incumbent systems.

However, interference from radar systems to LTE also needs to be studied. It is quite possible that commercial LTE system will operate effectively in the presence of radar interference. In LTE, the reference signals are transmitted at resource elements (time-frequency grids) of a subframe along with the data channels (PDSCH[5] and PUSCH[6]). The reference signals can be used for channel estimation of the desired signal and also the estimation of interference and noise. As LTE User Equipment (UEs) and Evolved Node Bs (eNBs) typically have at least 2 receive antennas, the channel estimate of the desired signal and the interference-plus-noise matrix can be used to design a spatial filter which effectively suppresses the interference. It is further noted that 2, 4 or even 8 receive antennas can be utilized at an LTE eNB and the larger number of receive antennas provides opportunity for even more powerful spatial filtering to suppress the interference.

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[4] Comments of Qualcomm Incorporated, February 20, 2013, to FCC NPRM, "Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550- 3650 MHz Band"

[5] PDSCH: Physical Downlink Shared Channel

[6] PUSCH: Physical Uplink Shared Channel

Furthermore, depending on the pulse duration of the incumbent signal, when part of one LTE subframe is interfered by it, the unaffected part can be still used in recovering the transmitted data when combined with transmission(s) from other subframe(s) with the Hybrid Automatic Repeat Request (HARQ)[7] feature. In summary, the air interface design of LTE which includes the reference signal design and HARQ operation, and the spatial filtering capability of modern eNBs and UEs need to be considered when evaluating the impact of radar signals to LTE to accurately evaluate the robustness and resilience of LTE to radar signals. We note that all of these LTE features were not modeled in NTIA Fast Track Report which used essentially a link budget calculation to determine the interference from one system to the other and comparing that interference to a noise level. Indeed, the NTIA simulations did not look into the behavior and performance of LTE system in the presence of radar interference.

We show simulation results hereafter of interference from radar into LTE Base Stations suggesting that commercial LTE macro-cells can operate effectively within the NTIA proposed exclusion zones which reached 557 kilometers inland from one type of shipborne radar into a base station located in the Gulf Coast region in the NTIA report. Nokia Networks' simulations use the NTIA radar and Irregular Terrain Model (ITM) propagation models but with a more accurate model of LTE macro-cell systems as defined in a ITU Recommendation of IMT – Advanced (IMT - A) Radio Interface Technologies (RIT)s.[8] The details about the assumptions and simulations can be found in the Appendix of this document.

[7] Hybrid automatic repeat request (Hybrid ARQ or HARQ) is a combination of high-rate forward error-correcting coding and ARQ error-control. In standard ARQ, redundant bits are added to data to be transmitted using an error-detecting (ED) code such as a cyclic redundancy check (CRC). Receivers detecting a corrupted message will request a new message from the sender. In Hybrid ARQ, the original data is encoded with a forward error correction (FEC) code, and the parity bits are either immediately sent along with the message or only transmitted upon request when a receiver detects an erroneous message.

[8] "Guidelines for Evaluation of Radio Interface Technologies for IMT-Advanced", ITU-R M.2135-1, Dec. 2009.

Our simulations led to the graphs plotted in Figures 1 and 2 below. As we can see from Figure 1, signal-to-interference-to-noise ratio (SINR) versus LTE symbol and subcarrier indices only undergo plummets on the symbols hit by the radar.

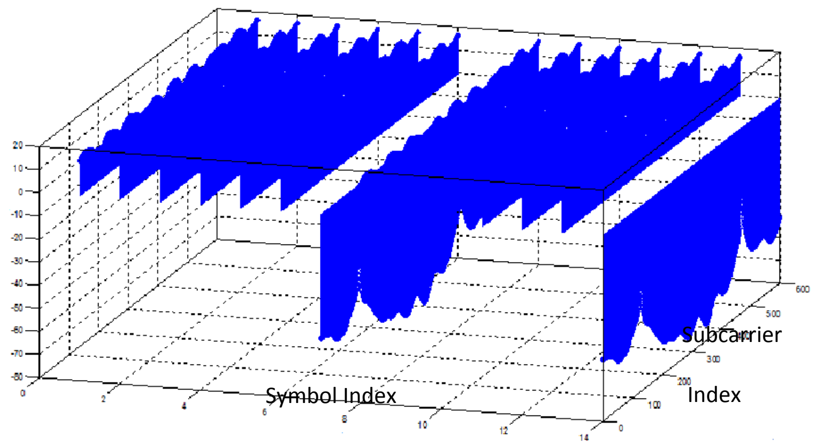


**Figure 1: SINR per symbol is reduced by radar interference at affected symbols.**

Besides, UE throughput plots in Figure 2 imply that the presence of the radar does reduce the UE throughput as expected but the reduction is modest at the studied LTE-radar separation distances (50, 100, 150, 200km).

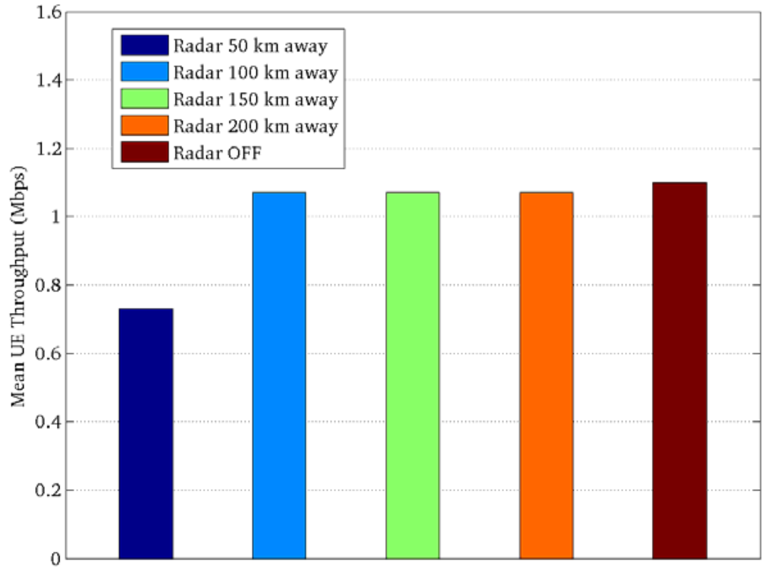


**Figure 2: Mean throughput of the UEs in the uplink at 50, 100, 150, 200km from radars**

The results presented above regarding interference from radar into LTE Base Stations macrocells already show some promising trends towards reduction of the exclusion zones and we recommend that the Commission take these initial results into account when reassessing the exclusion zones. We further agree with the Commission that the combination of small cells and spectrum sharing technologies could vastly increase the usability of the 3.5 GHz Band for wireless broadband and serve as a model for future coexistence among services in other spectrum bands.

Therefore, Nokia Networks intends to recalculate the exclusion zones using the NTIA's radar and propagation models but with operating parameters appropriate for LTE small cells and separation distances lower than 50km. Further optimization of the above-mentioned LTE features in the presence of radar interference can also be considered to further reduce the exclusion zones.

## III. MEASUREMENT CAMPAIGNS WOULD HELP DEFINE MORE ACCURATE PROPAGATION MODELS TO USE IN ASSESSING COEXISTENCE BETWEEN FEDERAL AND COMMERCIAL SYSTEMS

One of the big challenges in assessing coexistence of Federal and commercial systems in any band is the lack of suitable propagation model(s) between the Federal systems and the commercial networks. This is an issue we experienced firsthand in the various Commerce Spectrum Management Advisory Committee (CSMAC)[9] Working Groups that were set up to facilitate the implementation of commercial wireless broadband in the 1695-1710 MHz and 1755-1850 MHz band and are now experiencing in the 3.5GHz proceeding. One issue is the path loss when accounting for antenna patterns, locations of equipment at each end of the link, and operating power levels. In 3.5GHz, it primarily boils down to the path loss question as a key driver along with the pulsed nature of the signals. This affects our ability to predict what levels we can expect to see into the LTE receivers from the radar systems and what sort of levels we can expect to see from commercial networks into radar receivers. A key input to the system level simulations is the propagation model that will determine the impact that commercial LTE system will have on radar systems and vice versa. Until generally accepted and validated propagation models between various radar or other incumbent deployments and LTE small cell deployments are defined, there will always be doubts about the validity of the results obtained by simulations. We therefore recommend that the NTIA and/or the Commission should take the lead with incumbents and commercial wireless industry to conduct such measurements campaign to better characterize the propagation characteristics between the incumbent and commercial systems. We recognize that such measurements campaign can be costly and ambitious. However, we also

[9] US Commerce Spectrum Management Advisory Committee (CSMAC) http://www.ntia.doc.gov/category/csmac

believe that to achieve true sharing of spectrum, we would need to have such data to better predict interference between those systems which have to coexist in any given band.

Regarding the other incumbent system, Fixed Satellite Services (FSS), we recommend that if the Commission decides to enforce exclusion zones around the FSS earth stations, it should allow the CBRS users, especially the Priority Access Licensees to negotiate with individual FSS earth station licensees for smaller exclusion zones. The Commission should also explore other means of coexistence such as the use of field strength, power-flux density, or some other technical metric, measured in relation to the earth station's technical configuration (antenna characteristics, etc.) which might provide FSS earth stations with adequate protections while maximizing the available geographic area and bandwidth for CBRS Users.

## IV. THE COMMISSION SHOULD PROVIDE MORE CERTAINTY FOR PRIORITY ACCESS LICENSEES TO MAKE INVESTMENTS IN THE BAND

Nokia Networks is pleased to see that the *3.5GHz Small Cells FNPRM* further stresses the expansion of the Priority Access ("PA") tier to a broad class of potential users, including Mobile Network Operators ("MNOs"). Nokia Networks agrees that a wide class of users should be able to gain as unfettered access as possible to this spectrum and Priority Access Licensees should receive interference protection from General Authorized Access (GAA) users. We also support the inclusion of the existing 3650-3700MHz in the new regulatory framework to provide 150MHz of spectrum for mobile broadband services. The current users in the 3650-3700 MHz band could be incorporated into the SAS. Nokia Networks also supports a more traditional model with static frequency assignment for Priority Access Licensees as compared to the dynamic system set forth in the proposed rules, again to provide more predictability to the MNOs to make investments in that band and drive the ecosystem.

However, in order to provide more certainty for MNOs to invest in Priority Access Licenses (PALs), Nokia Networks continues to believe that a one year term as proposed by the Commission, even with the possibility for licensees to aggregate multiple consecutive PALs to obtain multi-year rights to spectrum within a given geographic area, will be insufficient to provide the predictability and certainty needed for MNOs and other potential PA users of the spectrum to make investments in the band. We continue to support 10-year terms for the new 3550-3650MHz band like what was developed for 3650-3700MHz band while keeping the proposed administratively-streamlined licensing of the Priority Access tier via the PALs. Even if the Commission ultimately views 10 years as too long, Nokia Networks believes that terms significantly more than a single year are warranted.

Similarly, we continue to support using license areas that are larger than census tracts, even if census tracts can be aggregated into larger areas. The administrative burden of managing some 74,000 census tracts is one issue, as is the fact that the tracts are not stable and can vary significantly in geographic size. Moreover, for MNOs and others likely to deploy in larger geographic areas and in many locations, it presents a model strongly divorced from typical network rollouts and adds an undesirable and unnecessary level of complexity. Nokia Networks at this time is not proposing specific license area sizes but is confident that entities likely to seek licenses will continue to do so.

Nokia Networks is also concerned that reserving 50 percent of spectrum for GAA would not make enough spectrum available for multiple Priority Access Licensees to invest in that band. For example, if there is a total of 100MHz of spectrum available, this means that 50MHz will be available for PALs. If we have five Priority Access Licensees interested in that spectrum, that would mean that only 10MHz is available to each licensee. We do not believe that 10MHz of spectrum along with the other uncertainties in this band would be enough to encourage MNOs to invest in the PALs. As a comparison, this would be four times less than the 40MHz that each operator in Japan is getting to deploy mobile broadband services in 3400-3600MHz. In other countries, where the 3.5GHz spectrum has been made available, each operator got more than 20MHz typically. We believe that GAA users should get whatever spectrum is not being used by Incumbents or Priority Access Licensees.

## V. A SIMPLIFIED TWO-TIERED SPECTRUM ACCESS SYSTEM (SAS) BASED ON LICENSED SHARED ACCESS (LSA) WOULD ALLOW QUICK AND RELIABLE DEPLOYMENT OF MOBILE BROADBAND SYSTEMS

Nokia Networks is pleased that the Commission proposes to adopt a Priority Access (PA) tier that corresponds to Nokia Networks' proposed ASA/LSA tier that includes MNOs.[10]

[10] See Nokia Solutions and Networks comments in GN Docket No. 12-354 "Amendment of the Commission's Rules with Regard to Commercial Operations in the 3550- 3650 MHz Band."

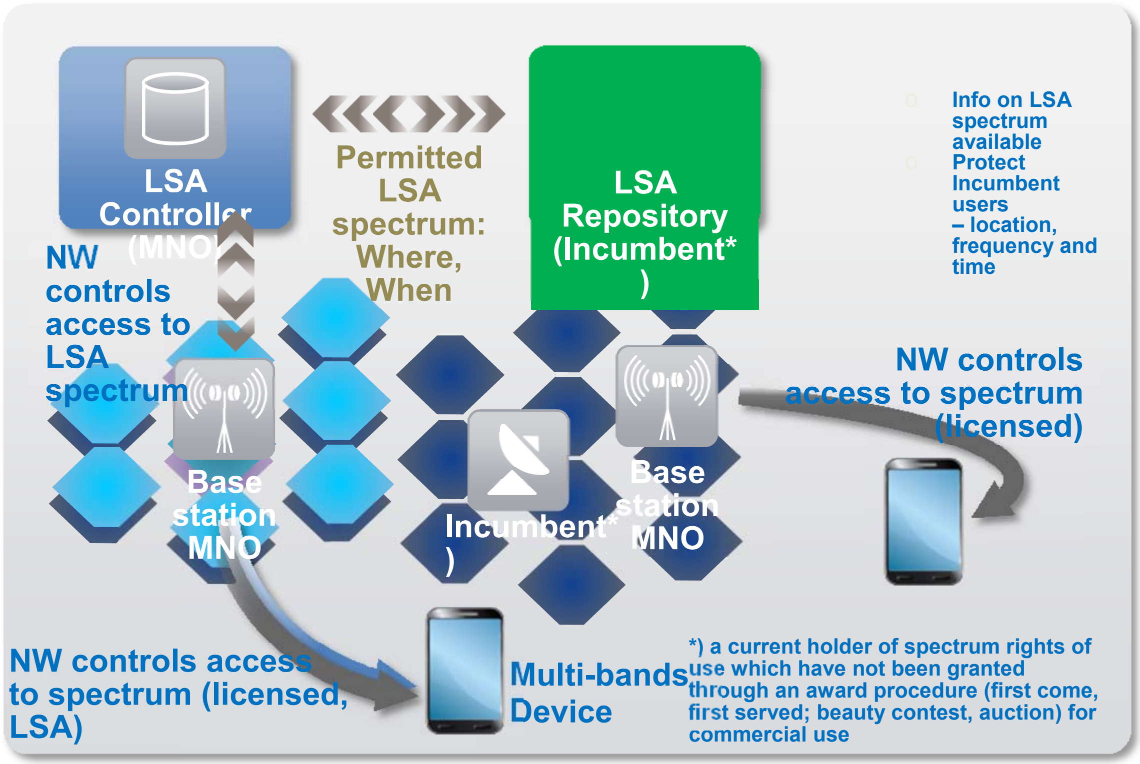


**Figure 3: Authorized/Licensed Shared Access (ASA/LSA)**

As explained above, the calculation of an exclusion zone where no other service can transmit can be quite complex and not always a good reflection of reality. Implementation of such exclusion zones, especially when they are large, can also be over-restrictive if the incumbent is not using the spectrum at all times at a given location and therefore an LSA licensee can use that spectrum. The benefit of LSA is that it exploits the geography/time/frequency realms to allow an LSA licensee to utilize the spectrum for mobile broadband on a shared and non-interference basis with the incumbents since the LSA licensee enjoys exclusive spectrum rights of use where and when the spectrum is not used by the incumbent. When the incumbent needs the spectrum back, the LSA licensees can evacuate the spectrum and can migrate to another spectrum block. Therefore, we continue to support a simplified two-tiered licensing model based on a “binary”

SAS that would only inform Priority Access Licensees whether or not they could operate in a given area or frequency range without causing harmful interference to incumbents.

Nokia Networks and its partners have demonstrated a live LSA system using commercial TD-LTE network and devices at the 2014 IEEE International Symposium on Dynamic Spectrum Access Networks (DySPAN) in Mc Lean, Virginia, April 1-4, showing that current LTE commercial standard-based equipment supports basic enablers that serve as a foundation for an LSA solution. [11] Future LTE releases and products enable additional capability through such as features as carrier aggregation and load sharing. Therefore, we still recommend that the SAS should not configure the network parameters and RF configurations of systems operating in the 3.5 GHz band. This configuration should be left to the Priority Access users, especially MNOs, through the use of a Controller similar to the one that Nokia Networks presented as part of its ASA/LSA proposal that could be used in 3550-3650 MHz to manage spectrum sharing between Federal incumbents and Priority Access users. The reasons why Nokia Networks recommends that a Controller function sitting inside a PA network and not the external SAS configures the network parameters include:

- Such configuration process requires deep insights into the PA licensee's radio access network.
- Such configuration requires access to information that is business sensitive for the PA licensee.
- There are many parameters to be configured taking into account the entire network layout and interactions of Base Stations (BSs), which is best managed by the network operator.

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[11] Marko Palola et al., "Live field trial of Licensed Shared Access (LSA) concept using LTE network in 2.3 GHz band", 2014 IEEE DySPAN, 1-4 April

- The PA network operator must have control to optimize traffic in its network.
- There is a real danger of "mis-configuration" from an external entity like the SAS.
- There are various internal elements to a network that an external SAS cannot and should not oversee.

However, the PA licensee should be responsible for compliance with technical requirements obtained from the SAS such as meeting certain interference thresholds. This can be accomplished via the Controller under the full control of the PA network operator.

Nokia Networks also agrees with the Commission's proposals to have multiple SAS Administrators and, consequently, multiple SASs to operate in the 3.5 GHz Band to ensure that consumers are provided with a robust set of choices in the marketplace. We also agree with the Commission's goal to institute a comprehensive approval process for SASs and SAS Administrators.

## VI. CONSIDERATIONS REGARDING THE EMISSION LEVELS AND GLOBAL ECOSYSTEM

The rules put forward by the Commission should allow the use of existing global 3GPP TDD LTE Bands 42 and 43, harmonizing with the rest of the world.[12]

- TDD Band 42: 3400-3600 MHz
- TDD Band 43: 3600-3800 MHz

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[12] See 4G Americas White Paper, *"Meeting the 1000x Challenge: The Need for Spectrum, Technology and Policy Innovations,"* October 2013, available at http://www.4gamericas.org/documents/2013_4G%20Americas%20Meeting%20the%201000x%20Challenge%2010%204%2013_FINAL.pdf.

In general, it is preferable if new spectrum is covered by an existing band to avoid having to create a new one in 3GPP. The Commission adopting TDD is the right way forward to create an ecosystem for the 3.5 GHz band. Band class harmonization helps to achieve economies of scale, enables global roaming, reduces equipment design complexity and improves spectrum efficiency. Indeed, with the Commission adopting TDD, the existing 3GPP Band 42 and 43 would cover the 3.5 GHz Citizens Broadband Radio Service (CBRS) band entirely. As illustrated in Figure 4, the first 50 MHz of the Commission's CBRS band, 3550-3600, is covered by Band 42 and the second 50 MHz, 3600-3650, is covered by Band 43. Note that if the Commission decided to extend the CBRS band up to 3700 MHz, Band 43 will still cover the extended portion. It would seem that a TDD band plan is more flexible and accommodating than a FDD band plan, especially if the Commission were to expand the CBRS band beyond 3550-3650 MHz in the future.

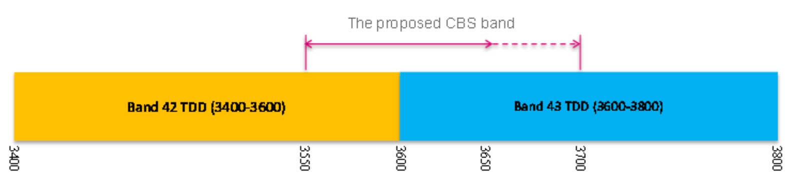


**Figure 4: 3GPP Bands 42 and 43 in relation to the CBRS band.**

However, beyond the band plan, the transmit power and emission limits proposed in the *3.5GHz Small Cells FNPRM* should also align with the 3GPP bands 42 and 43 requirements, especially for the End User Devices if we want the US to leverage the global bands 42 and 43 ecosystems.

Nokia Networks recommends that End User Devices should follow the 3GPP TS 36.101 standards including the allowed tolerance, *i.e.*, a maximum transmit power of 25dBm for 3.5

GHz bands 42 and 43.[13] LTE technology uses very sophisticated Transmit Power Control to adjust the transmit power of the LTE devices and prevent interference, ensuring effective spectrum sharing.

**Table 1: 3GPP LTE UE Power Class for 3.5GHz TDD bands 42 and 43**

| EUTRA band | Class 1 (dBm) | Tolerance (dB) | Class 2 (dBm) | Tolerance (dB) | Class 3 (dBm) | Tolerance (dB) | Class 4 (dBm) | Tolerance (dB) |
|---|---|---|---|---|---|---|---|---|
| 42 | | | | | 23 | +2/-3 | | |
| 43 | | | | | 23 | +2/-3 | | |

Minimum receiver standards for the systems likely to operate in this band should follow technical specifications of standards bodies such as 3GPP.[14] The Commission should not specify minimum receiver standards.

The *3.5GHz Small Cells FNPRM* proposes that the following Out-of-Band Emission limits to be applied to both the Citizens Broadband Service Devices (CBSD) and End User Devices:

- the power of any emission outside the fundamental emission (whether in or outside of the authorized band) shall be attenuated below the transmitter power (P) by at least 43 + 10 $\log_{10}$(P) dB, which is equivalent to -13dBm/1MHz.
- the power of any emissions below 3520 MHz and above 3680 MHz shall be attenuated below the transmitter power (P) in watts by at least 70 + 10 $\log_{10}$(P) dB, which is equivalent to -40dBm/1MHz.

While we support the use of the general emission limits of 43 + 10 $\log_{10}$(P) dB (-13dBm/1MHz), we wanted to point out that the use of 70 + 10 $\log_{10}$(P) dB (-40dBm/1MHz) at a

[13] *See* 3GPP TS 36.101 V12.1.0 (2013-09), "User Equipment (UE) radio transmission and reception (Release 12)."
[14] *Id.*

frequency offset of 30MHz, i.e., above 3650 MHz and 30 MHz below 3550 MHz would not comply with 3GPP[15] TS 36.101 Out-of-Band Emission limits of -25dBm/1MHz for 10MHz channels beyond a 10MHz frequency offset for End User Devices. This would imply that Band 42 and Band 43 UEs would not be able to operate under the emission limits proposed by the Commission. We therefore recommend that the Commission defines Out-of-Band Emission limits that complies with the 3GPP specifications and would allow the use of Bands 42 and 43 ecosystem in the USA.

**Table 2: 3GPP General LTE spectrum emission mask**

| Spectrum emission limit (dBm)/ Channel bandwidth | | | | | | | |
|---|---|---|---|---|---|---|---|
| **$\Delta f_{OOB}$ (MHz)** | **1.4 MHz** | **3.0 MHz** | **5 MHz** | **10 MHz** | **15 MHz** | **20 MHz** | **Measurement bandwidth** |
| ± 0-1 | -10 | -13 | -15 | -18 | -20 | -21 | 30 kHz |
| ± 1-2.5 | -10 | -10 | -10 | -10 | -10 | -10 | 1 MHz |
| ± 2.5-2.8 | -25 | -10 | -10 | -10 | -10 | -10 | 1 MHz |
| ± 2.8-5 | | -10 | -10 | -10 | -10 | -10 | 1 MHz |
| ± 5-6 | | -25 | -13 | -13 | -13 | -13 | 1 MHz |
| ± 6-10 | | | -25 | -13 | -13 | -13 | 1 MHz |
| ± 10-15 | | | | -25 | -13 | -13 | 1 MHz |
| ± 15-20 | | | | | -25 | -13 | 1 MHz |
| ± 20-25 | | | | | | -25 | 1 MHz |

Nokia Networks also recommends that the maximum conducted output power and maximum Equivalent Isotropically Radiated Power (EIRP), especially for the baseline CBSDs should be at least 6dB higher to be consistent with the 2.4GHz ISM and 5GHz U-NII power levels as defined in the recent Commission's 5GHz Report and Order[16] if power must be summed across all antennas and antenna elements according to the *3.5GHz Small Cells*

[15] 3GPP TS 36.101 V12.1.0 (2013-09), 3rd Generation Partnership Project; Technical Specification Group Radio Access Network; Evolved Universal Terrestrial Radio Access (E-UTRA); User Equipment (UE) radio transmission and reception (Release 12)
[16] ET Docket No. 13-49, Report and Order, Released April 1 2014, "In the Matter of Revision of Part 15 of the Commission's Rules to Permit Unlicensed National Information Infrastructure (U-NII) Devices in the 5 GHz Band"

*FNPRM*.[17] We recommend that the Commission adopts a 30 dBm (per 10 megahertz) peak transmit power and a maximum EIRP of 36dBm (per 10 megahertz) for CBSDs that are not operating in rural areas.

**Table 3: Nokia Networks' Proposed Maximum Conducted Output Power and Maximum EIRP for CBSDs**

| | | Maximum Conducted Output Power (dBm/10 megahertz)** | Maximum EIRP (dBm/10 megahertz) |
|---|---|---|---|
| **CBSD** | **Baseline*** | **30** | **36** |
| 1. *Baseline is all cases not qualified under rural or fixed PTP. | | | |
| **2.** ** Maximum Conducted Output Power | | | |

## VII. CONCLUSION

Nokia Networks is encouraged by the progress reflected in the *3.5GHz Small Cells FNPRM* in terms of moving towards enabling the availability of the 3.5 GHz band for use in the provision of mobile broadband services. While cleared, exclusively licensed spectrum remains the top priority for the commercial wireless industry, the 3.5 GHz band has some unique characteristics that promise to make licensed sharing a viable and interesting proposition in this particular instance.

If commercial users of this band are not able to cover 60 percent of the population because of the large exclusion zones along the coastline, there will be limited interest to invest in this spectrum where it is needed. Nokia Networks shared some initial simulation results suggesting that commercial LTE macro-cells can operate effectively within the NTIA proposed

[17] See Proposed Section 96.38 – General Radio Requirements in *3.5GHz Small Cells FNPRM*

exclusion zones in the presence of interference from radar systems. We found out that accurately modeling the radar and LTE systems as well as the propagation characteristics between the radar and LTE systems will go a long way in assessing precisely the interference impact from one system to the other. We intend to redo the simulations with LTE small cells and share the results with the Commission in the future. We therefore believe that it is premature for the Commission to enforce the large NTIA exclusion zones and that further study is needed. We also recommend that the Commission and/or NTIA should take a lead role in conducting measurement campaigns with the incumbents and interested parties to define the propagation models in 3.5GHz.

Nokia Networks strongly supports the Commission's proposal to provide open access to a Priority Access (PA) tier for any entity interested in operating in a quality-of-service environment, including importantly mobile network operators that are feeling the effects of constantly escalating consumer demand for improved mobile broadband speeds and coverage. Such a PA tier functionally is equivalent to Nokia Networks' proposed Authorized Shared Access/Licensed Shared Access (ASA/LSA) tier. However, we caution that the licensing terms for the PALs should be closer to the traditional licenses in terms of the geographical coverage and duration of the licenses to make the spectrum more attractive for investments. We also consider that the GAA floor of 50 percent of available spectrum will similarly not provide enough spectrum to the Priority Access Licensees to encourage them to invest. To further provide the certainty, Nokia Networks continues to advocate the use of a simplified SAS based on LSA. Additionally, Nokia Networks supports expanding the framework to include 3650-3700 MHz to make a total of 150 MHz available.

In addition, Nokia Networks recommends that the rules should align with 3GPP bands 42 and 43 specifications, especially for the End User Devices if we want the US to leverage the global 3GPP bands 42 and 43 ecosystems. In particular, the End User Devices transmit power and Out-of-Band emission should align with 3GPP TS 36.101 specifications of 25dBm and -25dBm/1MHz beyond a 10MHz offset respectively for 10MHz channels. We also recommend that the maximum conducted output power and maximum Equivalent Isotropically Radiated Power (EIRP), especially for the baseline CBSDs should be at least 6dB higher than the ones proposed by the Commission to be consistent with the 2.4GHz ISM and 5GHz U-NII power levels.

Nokia Networks believes that these measures as a whole would provide the right combination to enable commercial success while fostering innovative experimentation in the entirety of the 3550-3700 MHz spectrum range. We look forward to continuing to work with the Commission and our industry partners to enable the timely deployment of small cells in the 3.5 GHz band.

Respectfully submitted,

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# VIII. APPENDIX- RADAR TO LTE BASE STATIONS INTERFERENCE SIMULATIONS

In this Appendix, we simulate a pulsed radar which transmits pulses with operational parameters, adopted from NTIA's Fast Track Evaluation [1], to search for potential targets. We further use an LTE simulator developed at Nokia Networks to simulate macro-cells and place the radar close-by the cellular system to evaluate the interference into the LTE system.

*Radar Model*

The radar operational parameters are listed in Table 1, adopted from NTIA Fast Track Evaluation [1] as a shipborne radar approaching the littoral waters juxtaposed to a coastal region over which a 3.5 GHz LTE system operates. The LTE parameters, used in this simulation, are illustrated in Table 2. The radar distance from the LTE system is set to 50, 100, 150, and 200 km. It approaches the coastal region where LTE system is deployed similar to the scenario in Figure 1, and it affects one or more eNBs. The number of affected cells depends on the cell radii, radar distance to the eNBs, and the horizontal beamwith of the radar. In fact, the diameter of the radar radiation at distance R for a horizontal beamwidth $\Theta_a$ is given in equation (1), from which we see that the farther the radar from the coastline, the vaster the affected area, and the less the interference power. For a 0.81 deg beamwidth, we have:

$$d = 2R\tan(\theta_a) \approx 0.03R \quad (1)$$

The radar scans 360 degrees in azimuth with a speed of 30 rpm, generating a scan time 2 s over which 4000 pulses (Pulse Repetition Frequency 1/0.5 ms = 2000 Hz where Pulse repetition interval (PRI) is 0.5 ms) of 83 dBm each, excluding the antenna gain, are emitted. The radar pulse-width is 78 μs yielding in a bandwidth of 25.6 kHz. Moreover, due to the fact that horizontal beamwidth is 0.81 deg, there exists (360 degrees/0.81) 445 beam positions so that the antenna dwell time becomes (2s/445) 4.5 ms. As such all LTE equipment affected in each beam position are hit with 9 pulses (4.5/0.5).

The radar waveform during an antenna dwell time is plotted in Figure 2, including 9 pulses hitting on a segment of the LTE system during the relevant interval. Note that abscissa is in seconds ($10^{-3}$) and the ordinate is the pulse amplitude in Volts which is the square root of the pulse power in Watts. The radar antenna pattern was in accordance with NTIA Fast Track Evaluation [1], as a reference, whose normalized gain can be written as in equation (2), where the first expression gives the theoretical directivity pattern and the second equation provides with a mask equation based on which the pattern deviates from the theoretical value at an angle where the sidelobe decays -14.4 dB below the main beam, and the third term represents the backlobe. This NTIA formulation is adopted from [7]. The radar pattern is shown in Figure 3.

$$A = \begin{cases} \frac{\pi}{2}\left(\dfrac{\cos(\frac{68.8\pi\sin(\theta)}{\theta_{3dB}})}{(\frac{\pi}{2})^2 - (\frac{68.8\pi\sin(\theta)}{\theta_{3dB}})^2}\right) \\ -17.51\log_e\left(\frac{2.33|\theta|}{\theta_{3dB}}\right) \\ -50\,dB \end{cases} \quad (2)$$

**Table 1: Radar parameters from NTIA's Fast Track Evaluation [1]: Beamwidths were not given in the NTIA report, and we chose typical parameters marked with *.**

| **Parameters** | **Value** |
|---|---|
| Operating Frequency | 3.50 GHz |
| Peak Power | 83 dBm |
| Antenna Gain | 45 dBi |
| Antenna Pattern | Cosine |
| Antenna Height | 50 m |
| Insertion Loss | 2 dB |
| Pulse Repetition Interval | 0.5 ms |
| Pulse-Width | 78 μs |
| Rotation Speed | 30 rpm |
| Azimuth Beam-Width | 0.81 deg* |
| Elevation Beam-Width | 0.81 deg* |
| Azimuth Scan | 360 deg |
| Distance to LTE | 50, 100, 150, 200 km |

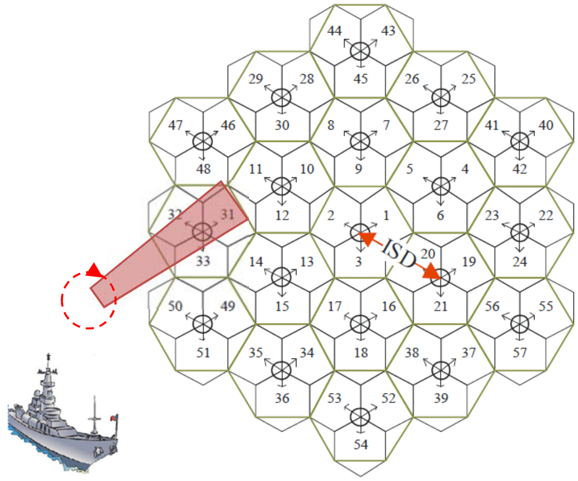


**Figure 1: Simulation scenario includes a pulsed radar approaching littoral zones juxtaposed to 3.5 GHz LTE cellular network.**

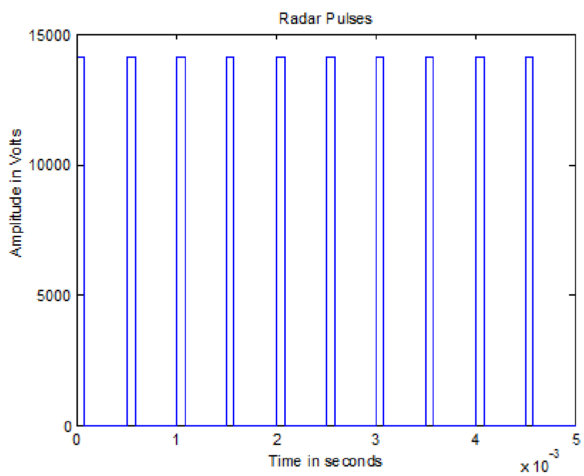


**Figure 2: Radar pulses during an antenna dwell time hitting on the LTE system ($10^{-3}$ term for time unit on abscissa)**

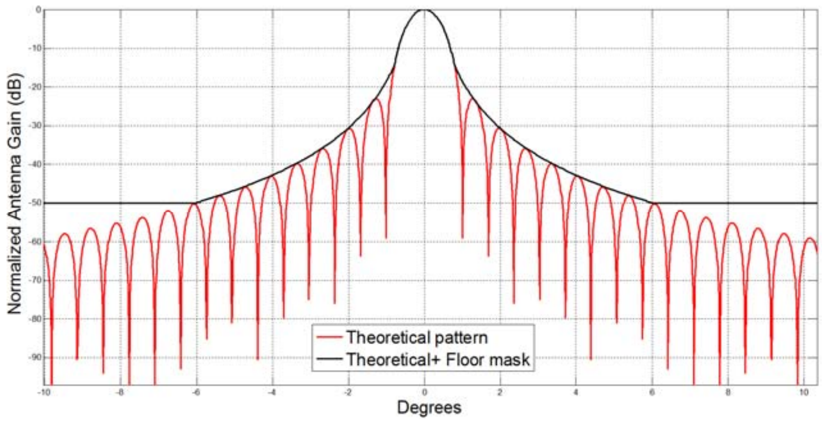


**Figure 3: Antenna pattern for radar adopted from [1]**

*LTE Model*

The LTE simulation is based on International Telecommunications Union (ITU) recommendations on International Mobile Telecommunications – Advanced (IMT - A) radio interface technologies (RIT)s [9] and leverages a full-buffer model to eschew from dropping packets. We focused on the urban macro-cellular environment which includes large cells.

As for the network layout, LTE eNBs are placed in a regular grid hexagonally and simulation can include up to 19 sites each with 3 cells. Furthermore, we leverage 120 deg sectors, each of which is equivalent to a cell (Figure 1). The simulation scenario will be similar to Figure 2 and when the radar approaches the shoreline, we consider separation distances of 50, 100, 150, and 200 km with LTE networks for the simulation. The parameters for the LTE system is illustrated in Table 2, adopted from ITU-R M.2135-1 [9].

The LTE eNB antenna pattern per sector is as equation (3) [9], where i = {A, E} for which $A_A$, $\Theta_A$ and $A_E$, $\Theta_E$ represents the antenna pattern, angle off the boresight in the direction of azimuth and elevation respectively where $-180^\circ \leq \Theta_A \leq 180^\circ$, $-90^\circ \leq \Theta_E \leq 90^\circ$. Downtilt for the antenna is $\Theta_A = 0^\circ$ and $\Theta_E = 15^\circ$, $A_m = 20$ dB is the maximum attenuation, and $\Theta_{3dB}$ is the 3dB beamwidth.

$$A_i(\theta_i) = -\min\{12(\frac{\theta_i - \theta_{i,t}}{\theta_{3dB}})^2, A_m\} \qquad (3)$$

Then, the combined antenna pattern can be calculated as equation (4). The UE antennae are omnidirectional and that is why their gain in 0 dB in Table 2.

$$A = -\min\{-(A_A(\theta_A) + A_E(\theta_E), A_m\} \qquad (4)$$

Furthermore, we used a WINNER II channel model [10], a stochastic geometry model, based on the recommendations from ITU-R M.2135-1 [9], with the pathloss equations (5) and (6) for the line-of-sight (LoS) and non-LoS (NLoS) regions respectively, where in the latter case *W* and *h* indicate average building height and street width in that order and in the former case c = $3\times10^8$ m/s is the propagation velocity in the free space. It is worth mentioning that these equations are tailored to the urban macro (UMa) environment that we selected for our simulation scenario.

$$L_{LoS} = \begin{cases} 22\log(d_1)+28+20\log(f_c); 10<r<r_{BP}, r_{BP}=4(h_{eNB}-1)(h_{UE}-1)\dfrac{f_c}{c} \\ 40\log(r)+7.8-18\log(h_{eNB}-1)-18\log(h_{UE}-1)+2\log(f_c); r_{BP}<r<5000 \end{cases} \quad (5)$$

$$L_{NLoS} = 161.04-7.1\log(W)+7.5\log(h)-(24.37-3.7(\frac{h}{h_{eNB}})^2)\log(h_{eNB})+$$
$$(43.42-3.1\log(h_{eNB}))(\log(r)-3)+20lo(f_c)-(3.2\log^2(11.75h_{eNB})-4.97); 10<r<5000 \quad (6)$$

In the LoS equation, the first expression is in terms of $d_1$, which can be seen from Figure 4, where UE moves along the perpendicular street measured from the center of the LoS street. Once all the parameters are assigned, the procedure for generating the LTE simulation is in accordance with the Algorithm 1 below whose details are included in ITU-R M. 2135-1 [10]. The angle of arrival (AoA) spread, log (AoA), for UMa are 1.81 and 1.87, shadow fading is 0.2 and 0.11 dB, k-factor is 9 and N/A, deay distributions is exponential, and angle of departure (AoD) and AoA is Wrapped Gaussian, delay scaling parameter is 2.5 and 2.3, number of clusters is 12 and 20, number of rays per cluster is 20, per cluster shadowing is 3 for the LoS and NLoS cases respectively. For more information about these parameters refer to the ITU-R M. 2135-1.

The cluster power $P'_n$ and average power $P_n$ is calculated using the following equation (7) where $Z_n$ is the per cluster shadowing term in dB [10].

$$P_n' = \exp(-\tau_n \frac{r_\tau - 1}{r_\tau \sigma_\tau}) 10^{-\frac{Z_n}{10}}; Z_n \sim N(0, \xi^2)$$
$$Pn = \frac{P_n'}{\sum_{n=1}^{N} P_n'} \quad (7)$$

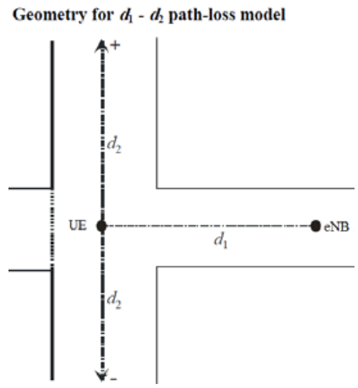


**Figure 4: LoS channel geometry with UMa scenario [10].**

**Table 2: LTE Parameters from Nokia Networks System Simulator Based on ITU-R M. 2135-1 [10].**

| Parameters | Value |
|---|---|
| Operating Frequency | 3.5 GHz |
| Layout | Hexagonal grid |
| Mode | TDD (In each TDD cycle, the uplink traffic ran for 3 ms of on-time, with a 2 ms off-interval for downlink traffic. So the DL/UL ratio was 2/3.) |
| Bandwidth | 20MHz |
| eNB/UE TX Power | 46/23 dBm |
| Indoor UE | 80% |
| eNB Antenna Gain | 17 dBi |
| Inter-site Distance (ISD) | 500 m |
| Minimum UE-eNB Distance | 25 m |
| eNB Antenna Downtilt | 12 deg |
| eNB, UE Antenna Height | 25, 1.5 m (Note that for the ITM model used for the interfering path between the radar and LTE eNB, another 25m above |

| | |
|---|---|
| | the sea level was used, leading to 50m for the ITM model) |
| UE Antenna Gain | 0 dBi |
| UE Distribution | Uniform |
| UE Mobility | 3 km/h, uniform direction |
| eNB, UE Noise Figure (NF) | 5, 9 dB |
| Thermal Noise | -174 dBm/Hz |
| Service Profile | Full buffer best effort |
| UEs per Cell | 10 |
| Channel Model | UMa |

**Algorithm 1: LTE Simulation High Level View (adopted from [10]).**

1. Set environment, network layout, and antenna parameters.

   1.1. Choose a scenario (here UMa).

   1.2. Specify UE & eNB quantities, locations, & array orientation.

   1.3. Specify UE and eNB antenna field patterns.

   1.4. Specify speed and direction of UEs.

   1.5. Specify center frequency.

2. Assign propagation conditions (LoS and NLoS).

3. Calculate pathloss for each UE – eNB link being modeled.

4. Calculate large scale parameters, i.e. delay spread, angular spread, Ricean k factor, and

shadow fading.

5. Generate delays.

6. Generate cluster powers.

7. Generate arrival and departure angles.

8. Random coupling of rays within clusters.

9. Channel coefficient generation.

10. Apply path loss & shadowing for channel coefficients.

*Propagation Model between Radar and LTE*

In order to account for the propagation loss, we will have free-space propagation loss within the light-of-sight (LoS) region defined by equation (8) and diffraction loss in the non-LoS (NLoS), modeled by the Irregular Terrain Model (ITM) in this study. We resorted to the ITM since the Fast Track Evaluation which had lead to the immense exclusion zones uses this model. The path loss propagation looks like Figure 5. Here, h1 and h2 represent antenna heights for the radar and the LTE eNB. For instance, if we focus on the case where both antennae are 50 m high, the path loss can be written down as equation (8), where the first component represents LoS free-space path loss and the others are linear approximations to the NLoS diffraction path loss.

$$L_{dB}(r)=\begin{cases} 20\log(f)+20\log(r)+32.45, r<50\,km \\ 1.6r+60, \quad 50\,km<r<80\,km \\ \frac{12}{77}r+175.532, \quad 80\,km<r \end{cases} \tag{8}$$

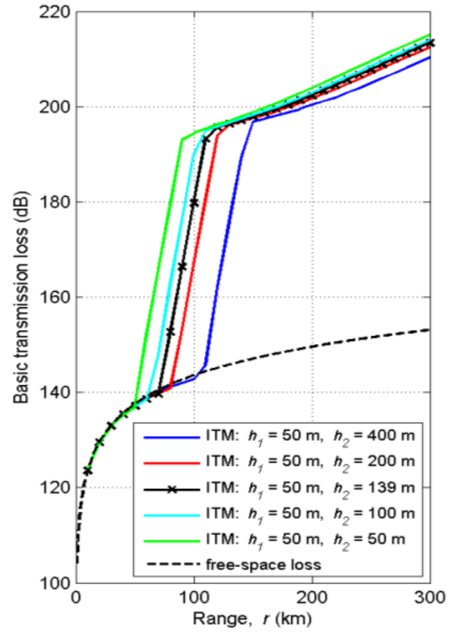


**Figure 5: LoS free-space and diffraction ITM loss models [3].**

*Results*

Simulation time is set to 5 s to obtain the impact of the radar on the LTE components affected during the simulation time interval. If we look at the signal-to-interference-to-noise ratio (SINR) versus LTE symbol and subcarrier indices, the plots as in Figure is obtained where the two SINR plummets are due to the radar pulses effecting LTE symbols in the frequency subcarrier indices shown in the Figure 6.

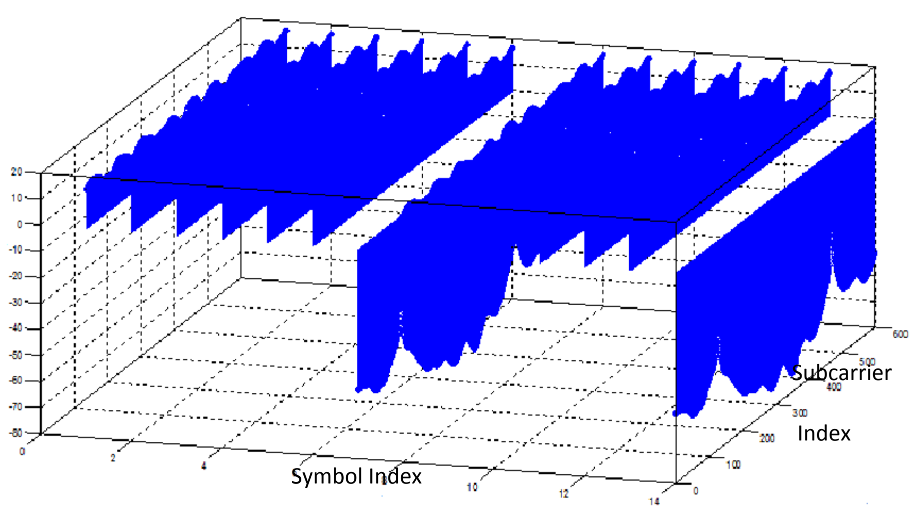


**Figure 6: SINR per symbol for an LTE hit with radar interference at which the SINR reduces significantly.**

As for the UE throughputs, they are plotted in Figure 7, from which we can observe that the absence of radar yields in a 1.1 Mbps UE throughput in the uplink (cherry bar). On the other hand, the presence of the radar decreases the UE throughput such that the closer the radar, the more severe the UE throughput degradation. However, the UE throughput reduction still stayed modest for the various separation distances studied.

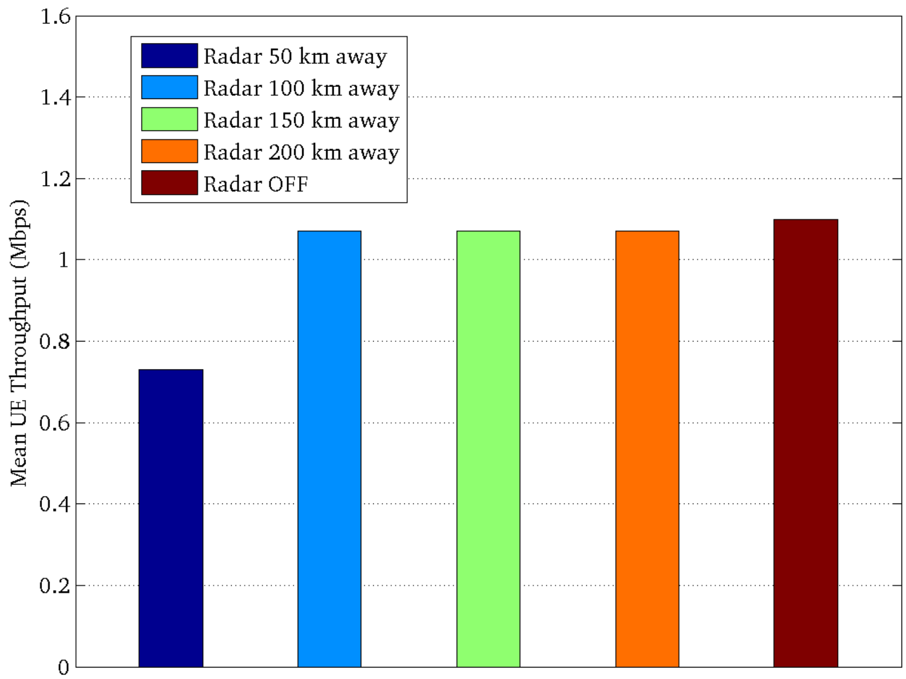


**Figure 7: Mean throughput of the UEs in the uplink in the absence of radar (cherry bar) and in the presence of the radar 50, 100, 150, and 200 km away**

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